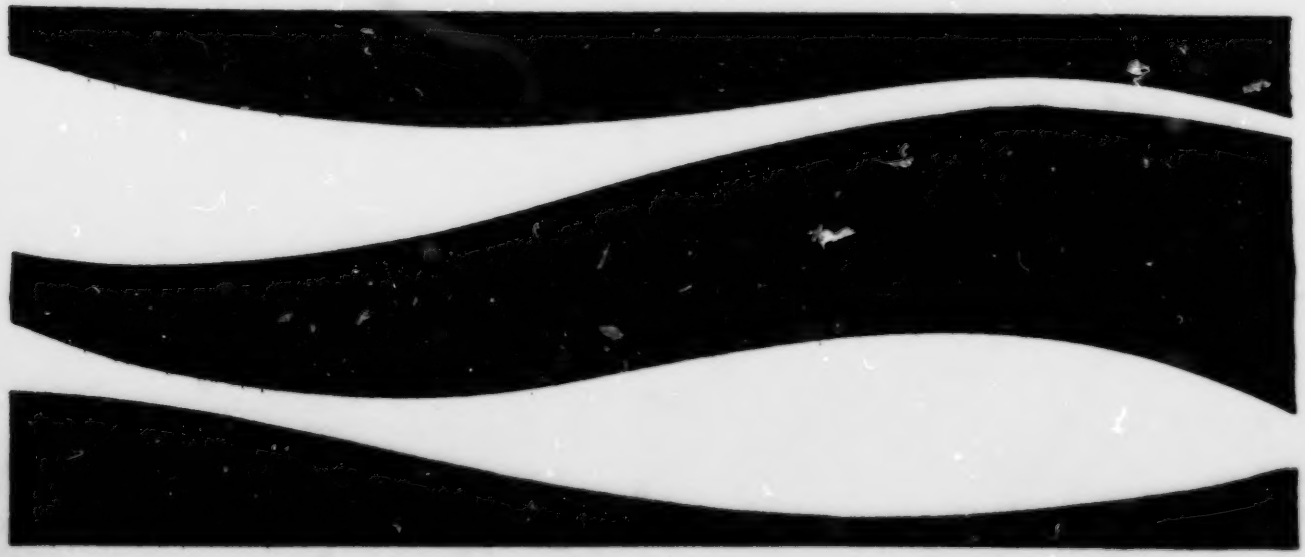
A Mariculturist's Guide To Potentially Harmful Marine Phytoplankton Of The Pacific Coast Of North America

Gregory Gaines and F.J.R. Taylor

Province of British Columbia
Ministry of Environment
Marine Resources Section
Fisheries Branch

Information Report No. 10



A MARICULTURIST'S GUIDE

TO POTENTIALLY HARMFUL MARINE PHYTOPLANKTON

OF THE PACIFIC COAST OF NORTH AMERICA

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PREFACE

This report was prepared under contract at the request of the Marine Resources Section, Fisheries Branch, Ministry of Environment.

It was undertaken as a technical service to fish farms in British Columbia; the initiative came from the knowledge and experience of staff in the Marine Resources Section who foresaw the probability of effects of some species of phytoplankton on salmon farms.

The Addendum to the report has been added as a recommendation for a standardized sampling procedure that should assist in monitoring and forecasting the development and geographical distribution of nuisance phytoplankton.

In addition the Addendum outlines the use and provides an illustration of a closing plankton net which is not covered in the text of the report.

Special thanks are due to Ed Black of the Finfish Unit of Marine Resources Section for his initiative in locating and working closely with Dr. Max Taylor of the Department of Oceanography at the University of British Columbia.

Over the past 10 years the Marine Resources Branch (now the Marine Resources Section) has undertaken to work closely with the best sources of expertise at the University of British Columbia in an attempt to bring academic expertise and experience to bear on practical mariculture problems. This report is an excellent sample of the utility of this strategic approach to problem solving.

We would like to acknowledge the extra time and effort that Dr. Taylor and Mr. Gaines have taken in assisting us and members of the industry in this endeavor.

The Ministry of Agriculture and Food (now the Ministry of Agriculture and Fisheries) kindly agreed to support the costs of the plankton monitoring project outlined in the Addendum.

An early draft of this report was supplied to all operating fish farms; accompanying that draft was a brief outline of measures that can be undertaken by farm operators to prevent and/or mitigate the effects of harmful phytoplankton. In the near future, further information will be provided on that subject.

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PREFACE

The shellfish farming industry in British Columbia has long been acquainted with the hazards created by undesirable phytoplankton, primarily those species causing "red tides". The finfish industry, however, has only recently become aware of such hazards, which may be even more severe for them. Simple monitoring of phytoplankton is not difficult and requires relatively little investment in equipment or time, and can provide forewarning of potentially harmful conditions. For example, this kind of monitoring is presently a routine aspect of mariculture in Japan, where the cost of phytoplankton-caused damage can exceed millions of dollars annually. This pamphlet is intended to be an introductory guide to phytoplankton monitoring for the mariculture industry of British Columbia, and includes references to more detailed works and authorities.

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INTRODUCTION TO PHYTOPLANKTON

The color of the sea is ever changing. Sometimes a deep blue, a muddy green or even reddish-brown, it is different from time to time and from place to place. The open sea is bluer than nearshore waters. In winter, the water is more transparent than in summer. Although this has been observed since the beginning of history, no one knew why until the last century.

There are very few large plants in the sea; most of what we see with the unaided eye are animals. On land, plants are the most noticeable living things in nature. They form the forests and grasslands that support humankind. Land animals are rare by comparison. But this is not true of the sea. The only obvious plants are seaweeds (also known as "algae" -- which means simple plants), and these grow only in certain areas on or near coasts. Ecologists have learned that it takes far more plant matter to support a given amount of animal matter. Thus, the sea seemed to present a paradox. The total amount of seaweed in the oceans could not possibly support the numbers of animals that live there.

The answer to both of these mysteries came about by the use of the microscope to look at seawater itself. Scientists found that in every drop of water taken from the surface of the ocean live hundreds of microscopic, one-celled plants, collectively called "phytoplankton". Because they are so small (about 1/50 mm), phytoplankton cannot effectively oppose water currents, and so are carried by them. (This does not mean they are inactive; many are vigorous swimmers on their own microscopic scale.)

These microscopic cells use carbon dioxide and the energy of sunlight in order to grow and reproduce, just as land plants do. They are responsible for the changing color of the ocean. Like land plants in temperate areas, the phytoplankton respond in the spring to increasing daylight by growing in abundance, making the water brownish-green and greatly reducing visibility. This annual event is known as the "spring bloom". Sometimes a similar discoloration occurs in the fall. In winter, the abundance is greatly reduced because of reduced daylight, and this results in greater transparency of the water.

Blooms can occur under other circumstances, too. Blooms so intense as to obviously discolor the surface of the water are commonly referred to by the color that results. Thus, a bloom of reddish-colored phytoplankton is also known as "red water" or "red tide". Blooms that intense usually cover a smaller area; for example, the protected end of an inlet. Areas that experience such local, intense blooms are usually calm and protected; more

exposed locations tend to be better mixed, which disperses such small "patches". In addition, red water is caused partly by cells accumulating right at the surface ofthe water. The concentration decreases rapidly within a few centimetres below the surface. It is not uncommon, however, for phytoplankton to form dense layers well below the surface, even if they are rare at the surface.

In most cases, phytoplankton are eaten by "zooplankton", the animals that drift with them. Zooplankton are usually less than 1 cm in size. Animals larger than this usually cannot eat things as small as phytoplankton. There are some notable exceptions, however. Bivalve shellfish (e.g., clams, oysters and mussels) as well as certain fishes (e.g., anchovies and herring), use their gills as seives to strain tiny phytoplankton cells out of the water. In addition, they and many other fish and shellfish have microscopic larvae that temorarily drift as zooplankton too, feeding directly on phytoplankton. As the larvae grow, they eat larger and larger food. In short, both fish and shellfish depend almost directly on phytoplankton for survival.

COMPOSITION OF PHYTOPLANKTON

In British Columbia, as in most oceans, phytoplankton can be divided into two competing kinds of algae: those that swim and those that do not (but are suspended in the water by other means). The most important non-swimmers are the diatoms. Swimming phytoplankters are called flagellates, of which the most important for the present purpose are the dinoflagellates. Very little is known about British Columbia phytoplankton, especially north of Vancouver Island; but the phytoplankton appear to be similar to those on the coasts of Norway, western Japan, Chile, western South Africa and eastern Canada (Harrison et al., 1983).

Diatoms

These algae are surrounded by silica shells that fit together like the two halves of a medicine capsule. Very often, they have spiny projections of various kinds. They cannot swim, but some forms that live on the sea bottom can "glide", or move slowly along surfaces. Diatoms dominate the phytoplankton throughout most of the year, especially in the spring, when cool temperatures, high nutrient levels and well-mixed water favor them over other groups. Thus, the general spring increase in phytoplankton (the "spring bloom") consists almost entirely of diatoms. In the winter months, when phytoplankton are scarce, diatoms are still prominent.

Nearly all diatoms are beneficial. However, the chain-forming diatom Chaetoceros convolutus damages fish gills (see below).

Perhaps the most important condition favoring diatoms over other phytoplankton is mixing or turbulence. Because diatoms cannot swim, they tend to sink. The only way they can remain in the lighted, upper portion of the sea is to be carried there and kept circulating by water movement. This requires wind, and so is greater offshore or on exposed coasts. Thus, phytoplankton dominated by diatoms indicates well-mixed, nutrient-rich water and relatively little threat to mariculture.

Flagellates

These organisms swim by means of one or more whiplike extensions ("flagella") that beat very rapidly to propel the cell through the water. This allows them to travel between the well lighted surface waters and the nutrient-rich deeper waters. Thus, flagellates are able to alternately take advantage of both resources even though the resources are separated in space. In calm waters, then, flagellates usually dominate over non-swimming phytoplankton.

Dinoflagellates are perhaps the most important flagellates for mariculturists to be aware of, because of their involvement in paralytic shellfish poisoning (below). They have two flagella, one of which trails behind the cell, the other is usually confined in a groove that encircles the equator of the cell. Many dinoflagellates are covered by armour-like plates of cellulose arranged in characteristic patterns in different species (e.g., Fig. 14). This is often easier to see on preserved cells, as the soft parts tend to shrink away from the plates.

COLLECTING PLANKTON

There are two ways to collect plankton, and both are necessary in order adequately to assess the state of the plankton. In order not to miss phytoplankton accumulations beneath the surface, it is necessary to use a plankton net to obtain a vertical slice of the water. However, net sampling is qualitative; it is inadequate for measuring numbers of organisms. To determine abundance, a bottle must be used, in order to obtain an unfiltered sample of seawater. Because blooms can develop very quickly, sampling should be carried out regularly and frequently. Weekly sampling is recommended.

The most useful plankton nets are made of monofilament nylon with mesh spacings of 20-30 micrometers. These are available from biological supply companies (e.g., Carolina Biological Supply Co., A. H. Thomas Scientific Co., Western

Scientific Supply Co., Wildlife Supply Co.) for less than $100. These nets consist of a hoop to which is attached a conical net (Fig. 1). At the end of the net (the "cod end") there is a container and/or a valve, to allow retrieval of the retained organisms. The net does not have to be big; a 10 cm mouth diameter is quite sufficient. More important is that the ratio of net length to net mouth diameter should be 3:1 to 5:1. A small weight (e.g., 1 kilogram) should be attached to the cod end of the net so that when the net is lowered into the water, it will sink cod end first. A line is attached to the middle of the mouth ring and the net is lowered into the water. In order to detect potentially harmful concentrations below the surface, it is best to lower the net down to near the bottom in shallow water or to a depth of about 20 m in deeper water, then raise it very slowly, finally lifting it out of the water and allowing it to drain until the sample inside the net is small enough to put in a container (a simple screw-capped jar holding 125-250 mls is good). If possible, the sample should be examined while the organisms are alive and fresh, because no preservative is entirely successful at preserving all species in a recognizable condition. Preservation does make rapidly swimming organisms easier to examine, however.

The best overall preservative is Lugol's Iodine Fixative. It is prepared by dissolving 100 g. potassium iodide in 1 litre of distilled water, then dissolving 50 g. of crystalline iodine in this. Finally, 100 mls of glacial acetic acid are added, and any precipitate is decanted or filtered out. These chemicals can be obtained through most scientific supply companies. The fixative is added to the sample until the sample is a weak tea color (about 1 drop fixative per 1 ml. of the sample). This will not only preserve cells, but it will color them dark brown, which makes them somewhat easier to see under the microscope.

Quantitative (bottle) samples can be taken with a screw-capped jar holding approximately 1,000 mls. This is simply filled with surface water, which is then preserved (with approximately 10 mls. Lugol's Iodine Fixative) and examined under the microscope. It is usually best to concentrate the sample to a slight, known degree, as it may otherwise be difficult to find cells unless they are in bloom concentrations. This can be done by pouring a portion into a tall, thin container like a graduated cylinder (obtainable from scientific supply companies) or any other graduated container, and allowing it to settle for 24 hours. The upper 9/10ths of the sample should then be siphoned off (pouring is less effective). What remains is now 10 times more concentrated than the original.

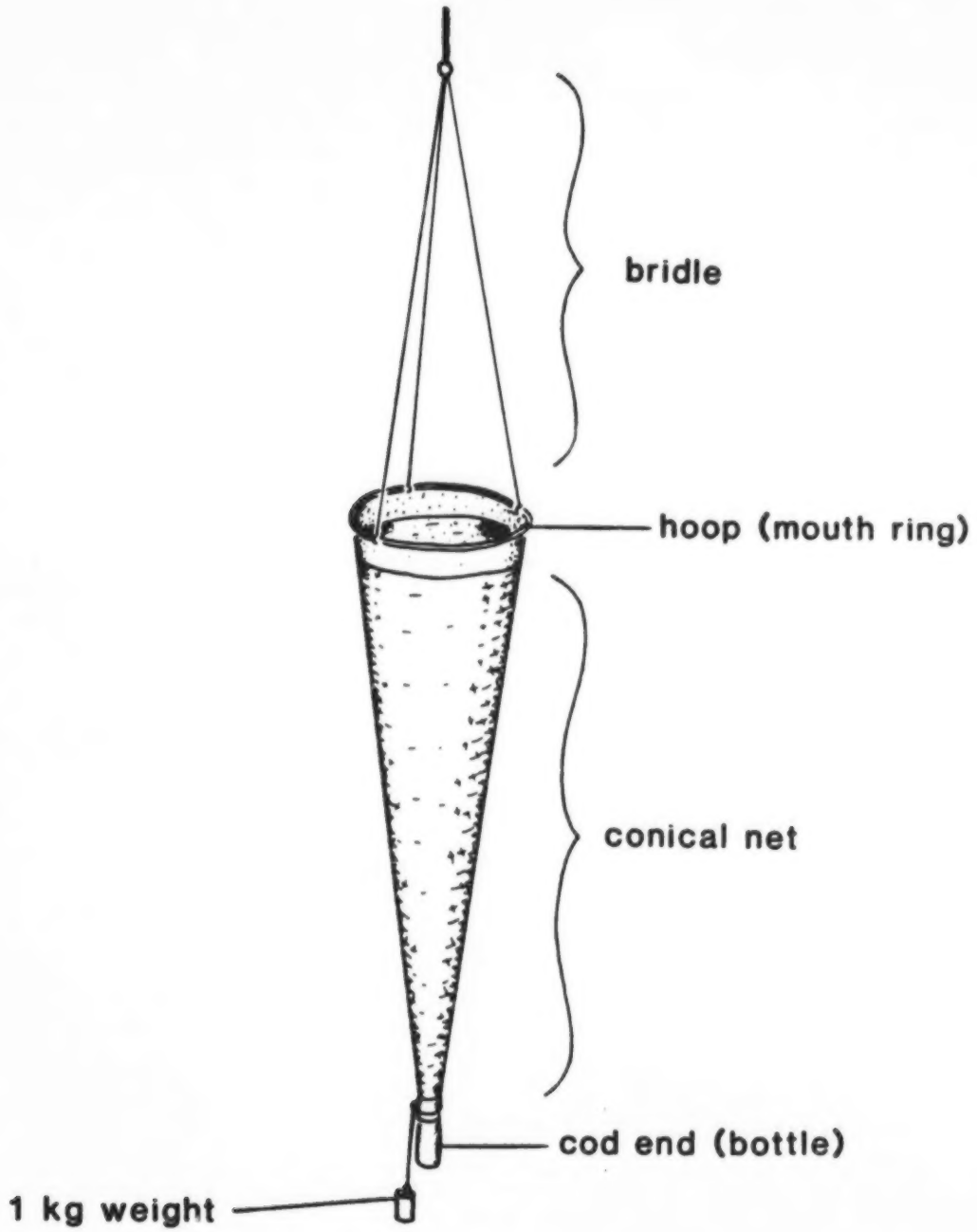


Figure 1. Diagram of a plankton net.

EXAMINING PLANKTON SAMPLES

The most important piece of equipment for examining plankton samples is a standard light microscope. These are available from most scientific supply companies (e.g., Canlab, Fisher, Western Scientific Supply Co.) and cost $1,000-2,000. More expensive models are certainly available, but the extra features are not necessary for the present purpose. The most important features to have are: (1) a binocular head, so that both eyes can be used; (2) several objective lenses in a revolving turret, for a variety of magnifications (we recommend 4X, 10X, 40X and 100X); (3) "parfocal" objective lenses, so that objects that are in focus with one lens will remain in focus when other magnifications are used; (4) an electric light source; (5) an adjustable "sub-stage condenser", for a sharp image; (6) an eyepiece micrometer and a stage micrometer, so that the sizes of cells can be measured (under the microscope, sizes can be confused easily). Microscopes are usually supplied with instructions for use. A good guide to microscopy is Photography Through the Microscope (1980), a paperback book published by the Eastman Kodak Company, Rochester, NY (Publication No. P-2, Cat. #152-8371).

In addition, you will need a few pipettes or eyedroppers, 3" x 1" glass slides and 22 mm square glass cover slips. A small glob of plasticine is also helpful for making "feet" at each corner of the cover slip to keep it from crushing the sample between it and the slide (Fig. 2).

COUNTING PLANKTON SAMPLES

Plankton samples can be counted easily by putting a drop of water from the quantitative (bottle) sample on a slide, covering it with a cover slip and counting the number of cells in that drop. If the sample was concentrated by the method above, multiplying the number by 2 gives the approximate concentration of cells in the water in cells/ml. Visible bloom samples should be counted without concentration. In this case, the number of cells counted in a drop should multiplied by 20 to give the concentration in cells/ml. If the number of cells is still too large to count conveniently, dilute part of the preserved sample by adding 1 part sample to 9 parts water (tap water will suffice) before counting. After dilution, the count must be multiplied by 200 to give the actual cell concentration in cells/ml.

HARMLESS BLOOM-FORMING ORGANISMS

Mesodinium rubrum (Fig. 3) is a common bloom-forming organism that does not appear to cause a health hazard to shellfish, finfish or humans. First reported to form a dark maroon red water in British Columbia in 1935 (Clemens,

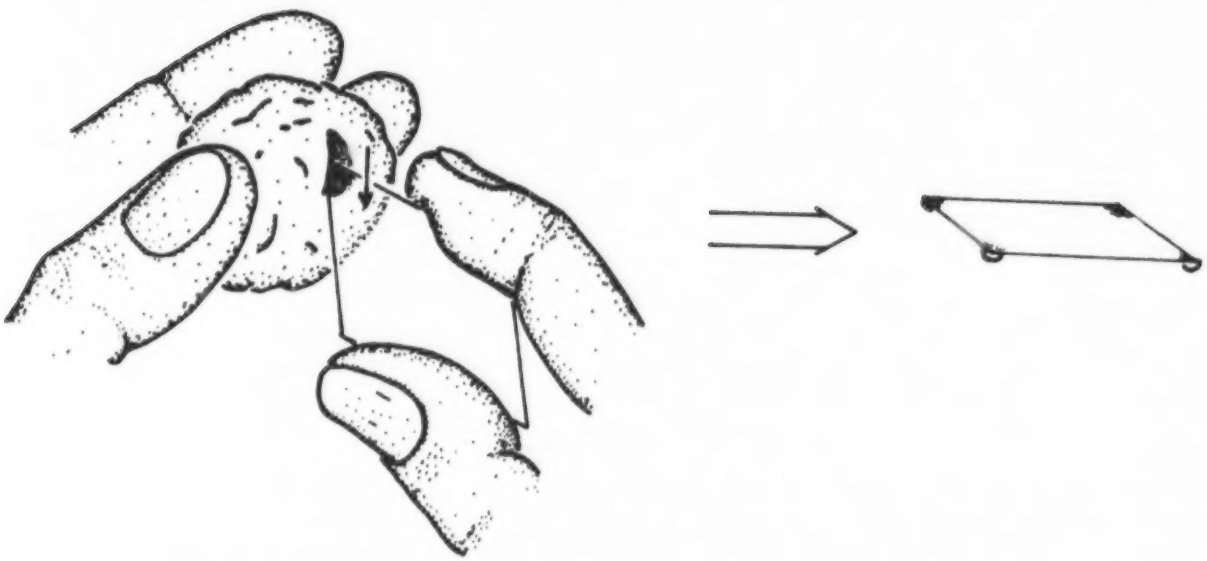
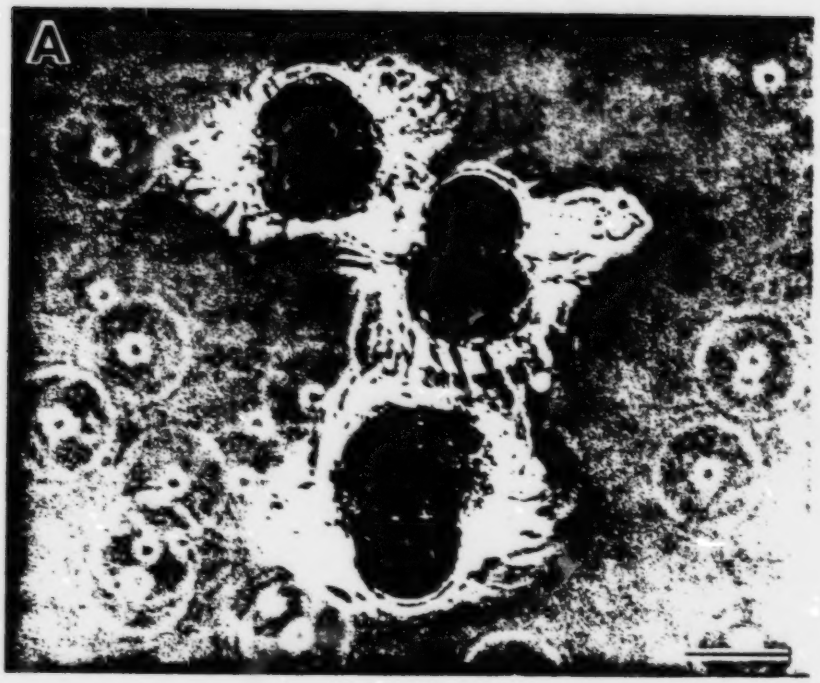


Figure 2. Using a ball of plasticine to put "feet" on glass cover slips. This holds the cover slip up off the slide during microscope examination of phytoplankton.



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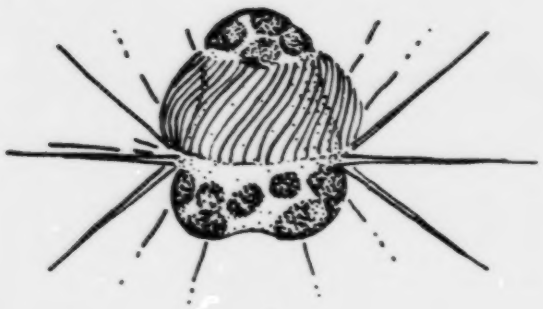

Figure 3. Mesodinium rubrum. This harmless organism produces red water in late fall to early spring. (A) These cells were fixed in Lugol's Iodine Fixative. Note the two-lobes, the dark color and the fringe around the middle of the cell. Photographed using 40X objective. (B) Drawing after Taylor et al., 1971. Scales = 20 micrometers.

1935), it commonly forms blooms from late fall to early spring.

This species is actually neither a diatom nor a flagellate. It is a ciliate, which means it has many flagella. These are arranged in a fringe around its middle. Under the microscope, it is recognizable when alive by its unique pattern of swimming: it jumps instantaneously from place to place, rather than swimming continuously while rotating, as most flagellates do. When preserved in Lugol's Iodine Fixative, it is not as easy to recognise, but can usually be distinguished by its size (about 30 micrometers), its fringe and its lumpy, two-lobed shape. It also stains very darkly. When preserved with formalin, the cell disintegrates.

HAZARDOUS ORGANISMS

Because nearly the entire food chain of the ocean depends on them, phytoplankton are almost always beneficial. However, under certain conditions, they can threaten certain other organisms, including humans. In British Columbia, the first recorded case of this happened in 1793, when members of Captain George Vancouver's crew were poisoned by shellfish that had acquired poisons manufactured by certain species of phytoplankton. Cultured pearl oysters worth $7 million were killed in Japan in 1933 (Fage, 1952). In 1972, in the Japanese Inland Sea, over $35 million worth of caged fish were killed by toxic phytoplankton (Iwasaki, 1979). Similar events have occurred in Norway and Denmark (Braarud & Heimdal, 1970; Tangen, 1977).

Sometimes, problems are due to the presence of bloom concentrations of certain species. However, most blooms are harmless or even beneficial (e.g., the "spring bloom"). On the other hand, some phytoplankton species can be hazardous even without reaching bloom concentrations.

A few species of phytoplankton manufacture extremely powerful poisons. British Columbia has several species of this kind, and the result is known as Paralytic Shellfish Poisoning (PSP). These toxins do not appear to directly harm local marine life. However, bivalve shellfish (clams, mussels, oysters), which ordinarily feed on plankton they filter out of the water, accumulate and concentrate these poisons and pass them on to whoever eats them. Because they are able to filter large volumes of water, shellfish can become toxic even when the toxic phytoplankters are only moderately abundant. Thus, "red tide" concentrations are not necessary in order for shellfish to become too toxic to eat.

Other phytoplankton species are directly toxic to marine life. These present a threat only if they occur in very high concentrations.

Some phytoplankton species produce large quantities of mucus (MacKenzie et al., 1983). Huge concentrations of these species in the water have been thought to clog the gills of fish and shellfish, but there is as yet no proof of this.

Even phytoplankton species that are not in themselves harmful can contribute to the killing of sea life under certain conditions. Ordinarily, phytoplankton give off more oxygen during the day (through photosynthesis) than they themselves use in growth and reproduction. However, if the water is stagnant, an overabundance of phytoplankton (of any kind) can run out of nutrients and die. Bacteria in the water grow rapidly on the decaying cells. The respiration of high concentrations of these bacteria can remove all of the oxygen from the water, a condition known as "anoxia". Fish and other marine life are killed by suffocation if they cannot escape the area in time. It can happen very quickly, even overnight, as has been reported in Nanoose Bay (Evelyn, 1972).

Details of these various effects of phytoplankton are given in the discussion of the organisms, below.

THREATS TO FINFISH CULTURE

Chaetoceros convolutus (Figs. 4 & 5) is the only diatom reported in this area to harm finfish directly (Bell, 1961). Its bullet-shaped cells have hollow spines extending from their corners, and form chains. The spines are studded with many smaller spines (spinules) along their length. Apparently, the spines break off and penetrate the gill membranes butt end first. The spinules, are directed toward the tip of the spine, thus preventing the setae from coming out. Death may be caused by capillary hemorrhage or by suffocation from an overstimulation of mucus or even from a secondary infection of the damaged tissue (Bell, 1961). Originally reported in lingcod, damage from Ch. convolutus has now been seen in sockeye, coho, chinook, chum and pink salmon held in cages (Brett et al., 1978).

From September through February, Ch. convolutus is found nearly everywhere in British Columbia waters, with the possible exception of protected bays and inlets. However, there have been no plankton studies extensive enough to be conclusive about this. The first report of damage was from Porlier Pass, Vancouver Island (Bell, 1961). Other reports come from Nanaimo (Bell et al., 1974; Kennedy et al., 1976, 1977; Brett et al., 1978). The concentration necessary for

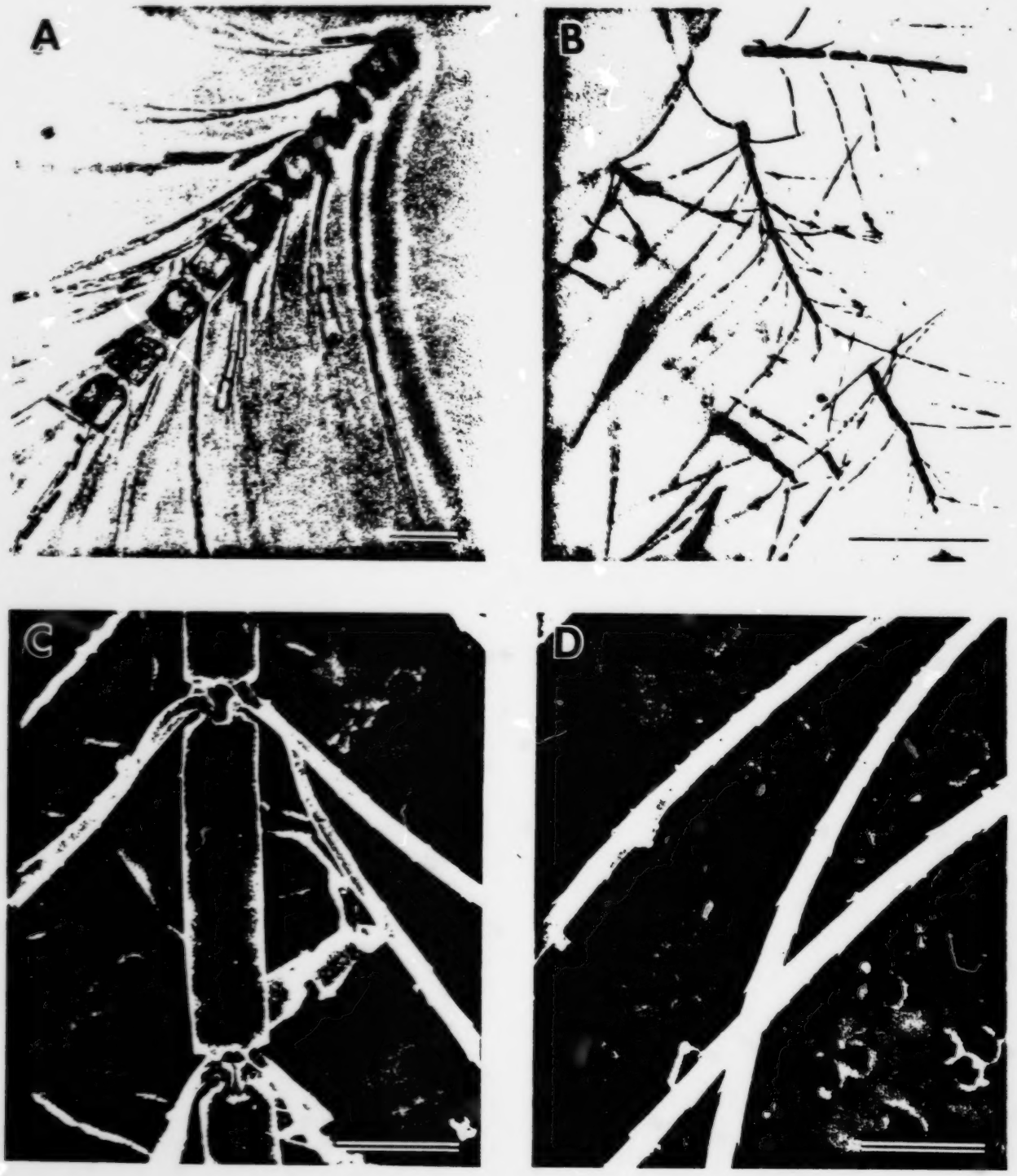

Figure 4. Chaetoceros convolutus. (A) Living chain of cells, showing light color, bullet-shaped cells and spines. Also visible are smaller, rod-shaped diatoms clinging to the chain. Photographed using 40X objective. (B) Chains fixed with Lugol's Fixative. Note the dark color. These cells are longer than those in 2A, but this is a common variation. Note also that portions of the spines are stained dark as well. Photographed using 10X objective. (C) Scanning electron microscope (SEM) view of part of a chain, showing the surface structure. (D) SEM view of the surfaces of several spines, showing the smaller spinules studding the surface. All scales = 20 micrometers.

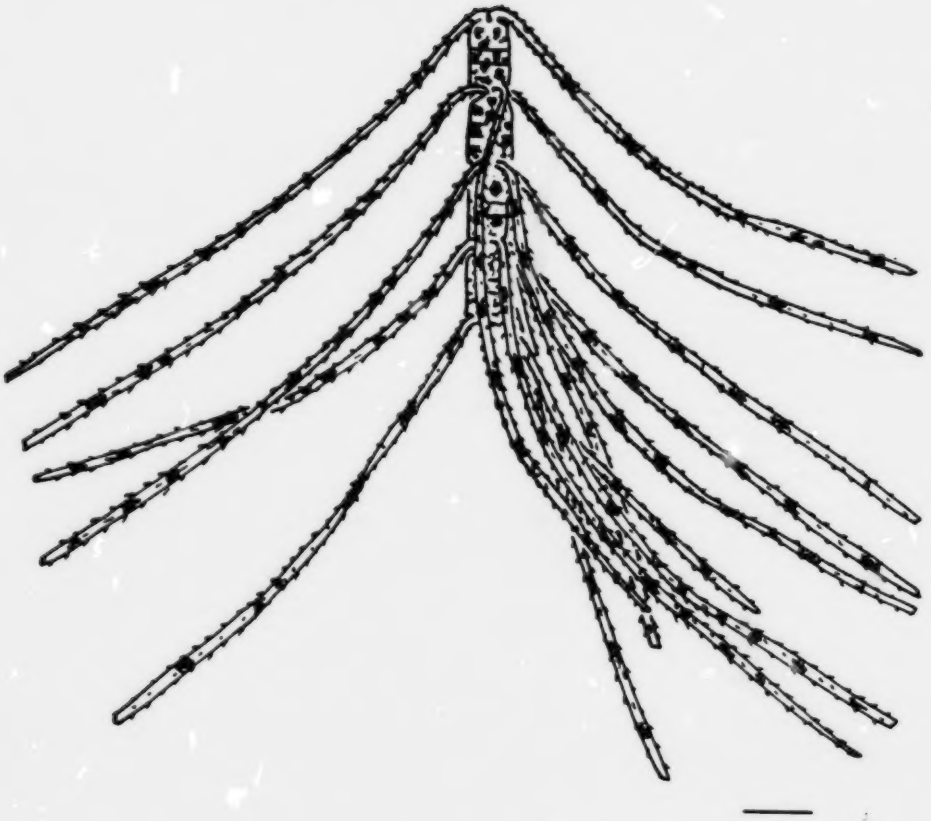

Figure 5. Chaetoceros convolutus. After Cupp, 1943. Scale = 20 micrometers.

damage appears to be approximately 5 cells/ml. (Bell et al., 1974).

There are more than 50 species of Chaetoceros, all of which possess spines (but not spinules) and form chains like Ch. convolutus, but do not harm fish. The most important characters marking Ch. convolutus are the hollowness of the spines and the bullet-like cell shape (but not the cell length).

An intense bloom of another diatom, Cerataulina pelagica, was reported to harm fish and bottom life off the coast of New Zealand, although the mechanism was unclear (Taylor et al., 1985). The presence of other potential fish-killers such as Prymnesium (see below) and Protogonyaulax leaves the question of cause open. It was suspected that mucus production by the diatom or low oxygen might have been contributing factors. In Scotland, a fish kill occurred while the diatom, Skeletonema costatum, was dominant; but the presence of 4 million cells per litre of "Flagellate X" (almost certainly Heterosigma, see below) makes it unlikely that it was this common, abundant diatom that caused the kill (Gowen, 1984). These diatom species are also found in local waters, but have not been reported to cause harm here.

Heterosigma akashiwo (Figs. 6 & 7) is a flagellate probably found in all temperate areas of the world. It has been linked to the deaths of caged fish in the Inland Sea of Japan, and in our area at many salmon farms in 1986, at Nanoose Bay in 1985 (J. Fulton, pers. comm.) and at Lummi Island in 1976. The mechanism(s) for this is unknown, but only caged fish appear to be affected. Other fish are presumably able to avoid the affected areas. Heterosigma is closely related to well-known toxic flagellates (Chattonella) that kill millions of fish in the Inland Sea of Japan (Okaichi, 1983; see below and Fig. 18). Heterosigma is a small (15-20 micrometers), potato-shaped organism with two flagella, numerous greenish-brown chloroplasts and many mucus-producing vesicles. It has been commonly misidentified as Olisthodiscus luteus and is almost certainly the fish-killer from Scotland known as "Flagellate X" (Gowen, 1984). Heterosigma is usually found in the upper 5-10 meters of the water. It is most common in the late spring to early summer, when it commonly causes red water in restricted areas and less often throughout the southern Strait of Georgia. It is of major concern in this area. For a detailed discussion of Heterosigma, see Appendix III.

The dinoflagellate, Gymnodinium sanguineum (Fig. 8), commonly produces red water in Esquimalt Lagoon (Watanabe & Robinson, unpubl. manuscript; Robinson & Brown, 1983). It was associated with oyster losses in Oakland Bay, Puget Sound, in 1929, 1935 and 1936 (Nightingale, 1936), but this

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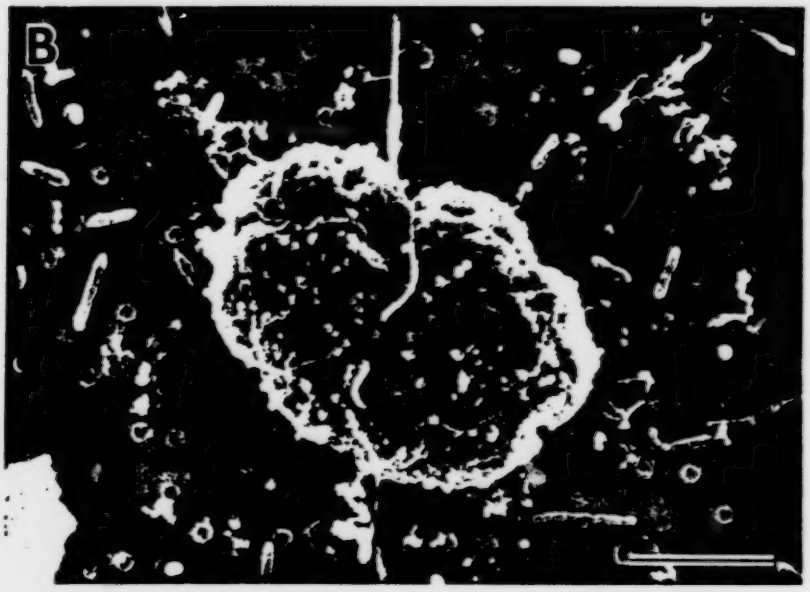

Figure 6. Heterosigma akashiwo. (A) Specimens preserved in Lugol's Iodine Fixative. Note the lumpy appearance and dark color. Photographed using 40X objective. Scale = 20 micrometers. (B) Scanning electron microscope view of a single cell, showing the two flagella emerging from near the center of the cell. The lumpy surface texture is also apparent. Rodlike bodies in the background are bacteria. Scale = 5 micrometers.

Figure 7. Heterosigma akashiwo, showing right side view (at left) and ventral view (at right). After Hara & Chihara, 1983. Scale = 20 micrometers.

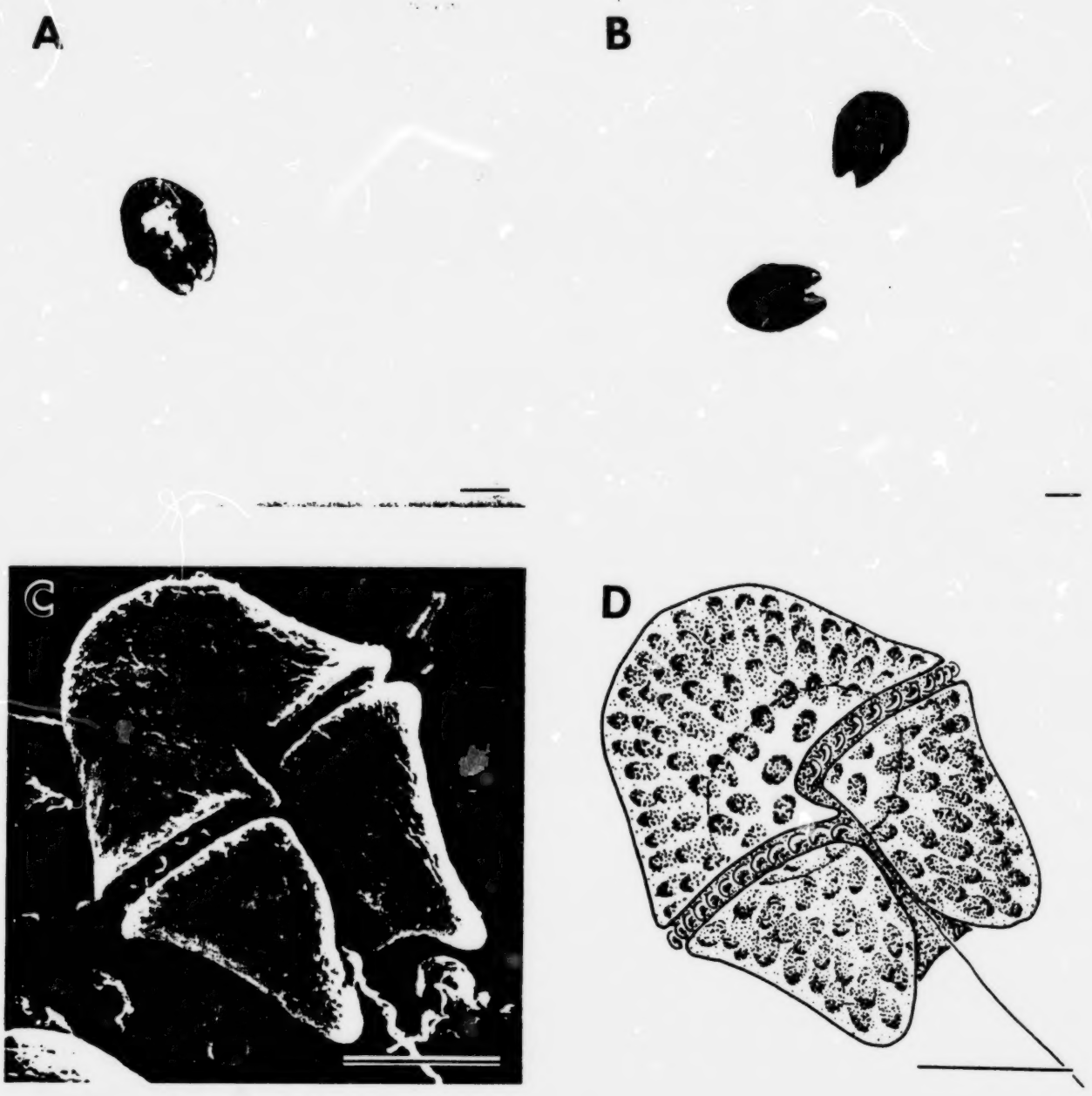

Figure 8. Gymnodinium sanguineum. (A) Living cell. Note the light color and the two posterior lobes of the cell. (B) Cells preserved with Lugol's Iodine Fixative, showing the two posterior lobes and the general body shape. (A) and (B) photographed using 10X objective. (C) Scanning electron microscope view of a cell, showing the cell shape and the two flagella. (D) Drawing after Hulburt, 1957. All scales = 20 micrometers.

has not been reported since. It has been suggested that the oyster losses may have been due to physical clogging of the gills. G. sanguineum is an extremely important food source for certain zooplankton and the larvae of warm water anchovy (Kiefer & Lasker, 1975; Lasker, 1975). On the other hand, there is evidence that some zooplankton avoid them (Fiedler, 1982).

G. sanguineum is a large cell (50-80 micrometers) that does not have plates on its surface. It is somewhat flattened, with two posterior lobes. It is found in British Columbia waters from May through October, especially in calm waters. Esquimalt Lagoon experiences almost annual blooms of G. sanguineum, beginning in July and becoming most intense in late September or early October, then declining rapidly (Watanabe & Robinson, unpubl. manuscript; Robinson & Brown, 1983). This species has not yet been reported from the eastern side of the Strait of Georgia, perhaps due to the strong river influence.

Noctiluca scintillans (Fig. 9) is an unusual dinoflagellate in several respects: it is predatory (it does not make its own food), it is large (up to 2 mm -- visible to the naked eye) and it floats at the sea surface (rather than swimming). Noctiluca is luminescent, and bright bioluminescence of the sea at night often signals its presence. Under the microscope, Noctiluca resembles a balloon. It can form intense areas of bright orange-red water, and eats virtually anything it can stuff into its mouth with its one flexible tentacle, including fish eggs floating in the water. Thus, it has been reported to cause damage to fisheries in some areas of the world (Devanesen, 1942; Prasad, 1953, 1958; Enomoto, 1956). In addition, it may be toxic to fish, as its inflated body contains a high concentration of ammonia (Okaichi & Nishio, 1976). However, Noctiluca forms frequent, intense blooms in British Columbia, yet fish appear to be completely unaffected. Noctiluca is usually found from May through October, especially in calm conditions and in protected areas.

Phaeocystis pouchetii (Fig. 10) is a very small cell, related to flagellates, but it lives embedded in large, spherical or many-lobed gelatinous masses that can be as big as 3 mm in diameter. It is of concern because fish avoid it; it has even been reported to deflect the migration paths of herring (Savage, 1930, 1932) and may be similarly noxious to other fishes as well (MacKenzie et al., 1983). The reason fish avoid Phaeocystis is unknown. It has been suggested that the mucus itself may simply clog the gills of fish (MacKenzie et al., 1983), or it may produce an unknown, noxious substance. In the North Atlantic and North Sea, where it is well known, it forms blooms in spring and autumn. In British Columbia, it has only been seen in the

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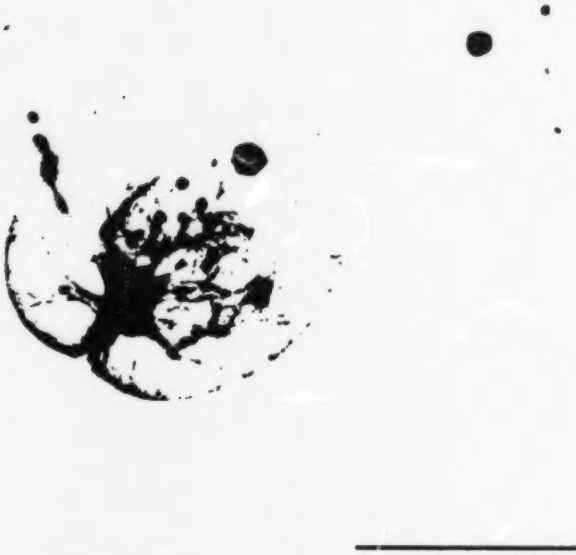

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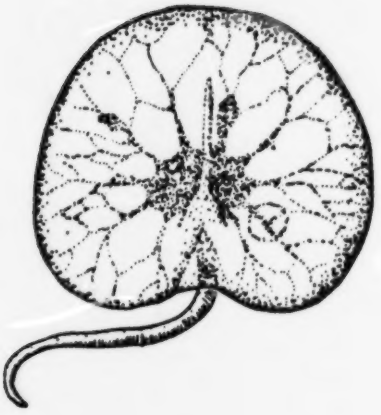

Figure 9. Noctiluca scintillans. (A) Photograph showing balloon-like appearance. Photographed using 4X objective. (B) Drawing showing the flexible tentacle which is used for feeding. After Kofoid & Swezy, 1921. Scales = 100 micrometers.

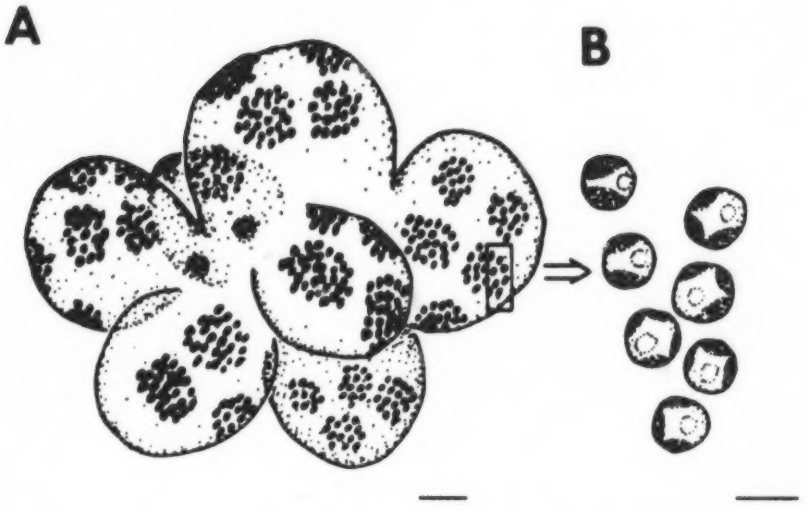

Figure 10. Phaeocystis pouchetii. (A) Colony of cells embedded in mucus, forming spherical or multi-lobed masses. Scale = 20 micrometers. (B) Individual cells within mucus. Scale = 5 micrometers. (After Lemmermann, 1964)

spring (February-March) at Jericho Beach, Vancouver, in Howe Sound and on the western side of the Strait of Georgia.

In Denmark, a fish kill was circumstantially linked to a bloom of a strange organism resembling the silicoflagellate, Distephanus speculum, but lacking a skeleton (Thomsen & Moestrup, 1985). This silicoflagellate is common in our waters, but has not been linked with harmful effects here.

There is also a possible threat to fish by dinoflagellates of the genus Protogonyaulax, which normally transmit their toxicity only through bivalves (see below). Zooplankton feeding on these phytoplankters can concentrate the toxins and pass them along to fish (White, 1980). In addition, there is one isolated report of a fish kill apparently directly caused by a Protogonyaulax bloom in the Faroe Islands (Mortensen, 1985). Twenty-seven metric tons of farmed rainbow trout and salmon were killed, and four cases of paralytic shellfish poisoning in humans were reported. The fish suffered acute histopathological damage to the gills. This symptom is similar to Ch. convolutus damage (above), so it is possible that the fish kill may have been caused by an unnoticed population of that diatom. Unfortunately, no mention was made of the presence or absence of diatoms in the water at the same time (Mortensen, 1985).

THREATS TO SHELLFISH CULTURE

In British Columbia, phytoplankton pose little danger to shellfish themselves. Shellfish on this coast are immune to the toxins produced by the dinoflagellates in question (below), although shellfish that have not been exposed to these phytoplankton are sensitive to it (Horstman, 1981). Here, however, the toxins accumulate in shellfish, then pass into any animal that eats the shellfish.

Paralytic Shellfish Poison (PSP)

The best known syndrome is called paralytic shellfish poisoning (PSP), synonymous with "red tide" to most British Columbians. It has killed sea birds (in British Columbia in 1962, and elsewhere -- Armstrong et al., 1978), other animals and humans (LoCicero, 1974; Taylor & Seliger, 1979; Ragelis, 1984; Anderson et al., 1985). These toxins are extremely potent: a pinhead-sized quantity (which can easily accumulate in just one 100 g. serving of shellfish) can be fatal. It is caused by certain dinoflagellates of the genus Protogonyaulax (previously referred to Gonyaulax). In British Columbia, three species were thought to be responsible. However, for most episodes of PSP, there are no plankton samples, so the organism responsible is not known. Currently, there is considerable doubt as to whether

these three forms are really separate species (Taylor, 1984, 1985).

As described above, the first case of PSP in British Columbia occurred among Captain George Vancouver's crew, at Poison Cove, Matheson Channel (Quayle, 1969). The next and most serious outbreak was in May, 1942, in Barkley Sound, when three died and eight became ill from eating clams and mussels. As a result, regular shellfish toxicity testing was instituted, leading to closure of the west coast of Vancouver Island and the Gordon Group of islands in Queen Charlotte Strait until 1953. During this period, no toxicity was found in Georgia Strait or on the mainland. Nevertheless, 60-110 cases of PSP appeared in October, 1957, near Comox, with oysters being implicated for the first time. In June, 1963, toxic clams were found along the entire coast from Cape Caution to the Alaska border, including the Queen Charlotte Islands. The subsequent closure of this area still remains in effect. In July, 1964, butter clams from the Cosine Island area, near Prince Rupert caused several cases of illness. In June, 1965, cockles from Malaspina Inlet killed one and made four ill. In November, 1972, manila clams from Toquart Bay and Barkley Sound, as well as oysters from Ucluelet and Bamfield, poisoned a total of 20 people, although all recovered. In June, 1975, two men became ill from eating mussels from Work Channel, near Prince Rupert. In May, 1980, one person was killed and eleven became ill from eating butter clams from Gilford Island and Shoal Harbour. In December, 1981, two people became ill after eating butter clams at Church House. The most recent confirmed PSP incident was in May, 1982, when five people became ill from eating mussels from Work Channel. These events are detailed in the publications by Quayle (1969) and Heritage & Quayle (In press).

A human lethal dose of about 500 micrograms can be obtained from about two million cells (Horstman, 1981; Kodama et al., 1982), equivalent to about two litres of a bloom. Since shellfish can filter tens of litres of water per day, they can acquire a lethal dose when the concentrations of dinoflagellates in the water are as low as 10 cells/ml., far from bloom concentrations.

Protogonyaulax catenella (Figs. 11 & 12) was the first organism to be linked to PSP, when an outbreak in 1927 near San Francisco killed six people and made 102 people ill (Sommer & Meyer, 1937). P. catenella is found along the entire coast of the northwest Pacific from British Columbia to California. It is common in Puget Sound and the bays of Juan de Fuca Strait and the open coast at least as far north as Barkley Sound, and in the Strait of Georgia as far as Saanich Inlet on the west and Boundary Bay on the east. It has not been found in the central Strait, but reappears again at about Comox on the western side and Malaspina inlet

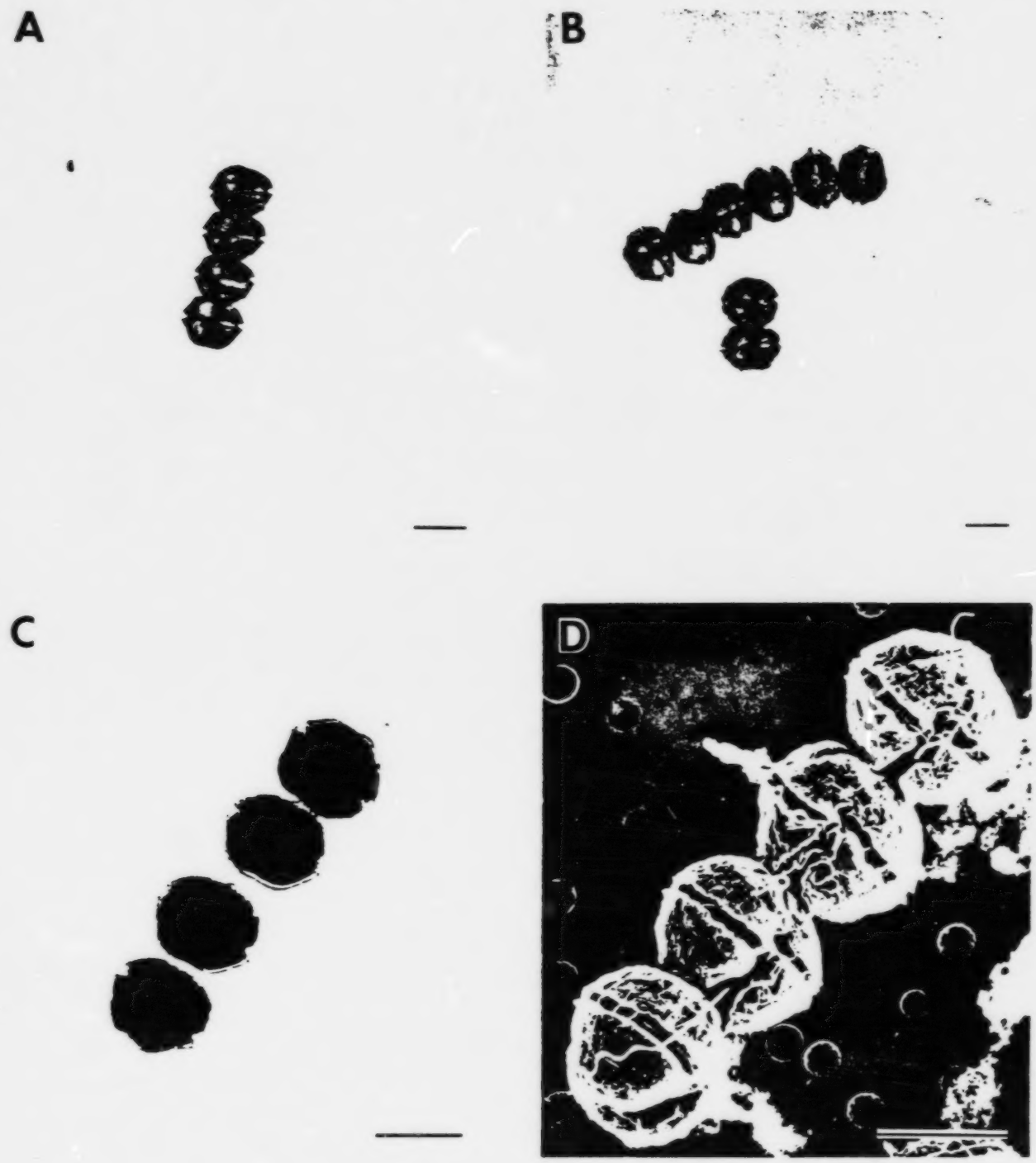

Figure 11. Protogonyaulax catenella. (A) A living chain of four cells. Note the light color and the equatorial groove around each cell. Photographed using 10X objective. (B) Long and short chains of living cells. Chains of this species can reach tens of cells in length. Photographed using 10X objective. (C) A chain of four cells preserved with Lugol's Iodine Fixative. Note the dark color, the flattened (hamburger-like) shape and the tendency of cells in a chain to separate when preserved. The rigid wall of plates surrounding the cells is also visible. Photographed using 40X objective. (D) Scanning electron microscope view of a chain of four cells, showing the surface appearance and the two flagella in grooves in the cell surface. All scales = 20 micrometers.

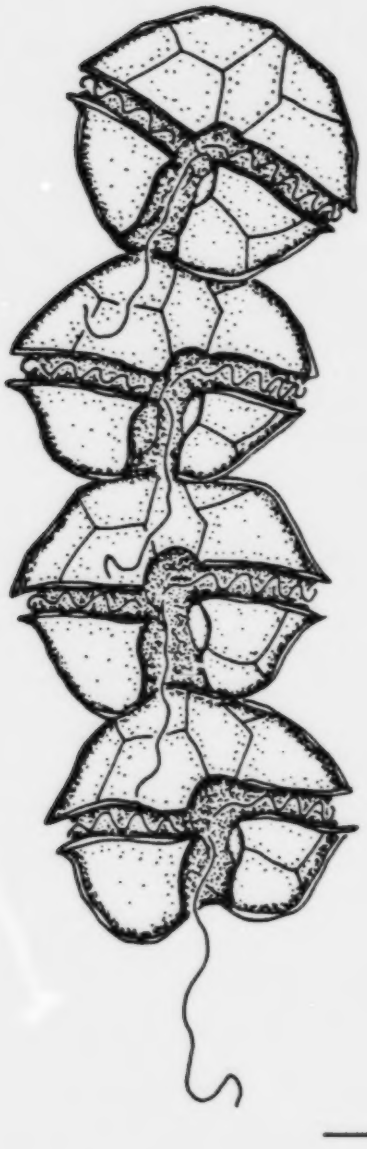

Figure 12. Protogonyaulax catenella. From an original by Taylor. Scale = 20 micrometers.

on the eastern side. It extends northward to the northern end of the Strait, but there are no phytoplankton records from there northward to Alaska. However, it has not been reported from Alaska. Thus, it seems to be excluded from Alaskan latitudes by cold temperatures (Taylor, 1984).

P. catenella is a relatively small dinoflagellate, about 35 micrometers long, and is covered by a wall made up of several large plates. This wall can be seen easily on preserved specimens. P. catenella can easily be recognized by its tendency to form long chains of hamburger-shaped cells. Although it is usually found in the warm months, especially in late summer or fall, it can appear as early as May or as late as October.

Protogonyaulax tamarensis (Figs. 13 & 14) (also known as Gonyaulax excavata) is similar to P. catenella except that it is usually more elongate (less hamburger-shaped) and does not form long chains. Instead, it exists mostly as single cells, occasionally a pair or rarely, chains of four. It is found in the central Strait of Georgia and in Alaska and the Arctic. Thus, it seems to tolerate colder temperatures and to prefer estuarine conditions (Taylor, 1985).

Protogonyaulax acatenella (Fig. 15), reported from an outbreak near Malaspina Inlet in 1965 (Prakash & Taylor, 1966), is probably just a variety of P. tamarensis (Taylor, 1984).

Diarrheic Shellfish Poisoning (DSP)

The dinoflagellates Dinophysis fortii and D. acuminata (Figs. 16 & 17) have been shown to be responsible for diarrheic shellfish poisoning (DSP), whose symptoms are diarrhea, nausea, vomiting, abdominal pain and sometimes chills (Yasumoto et al., 1980, 1984; Kat et al., 1982; Anderson et al., 1985). Other species of Dinophysis and Prorocentrum micans are suspected of containing DSP toxins, as well, but this has not been established. The species in question are common in British Columbia waters, but have never been known to cause harm here.

THREATS IN OTHER REGIONS

So far, we have restricted ourselves to phytoplankton organisms that occur on the Pacific Coast of North America. In other parts of the world, mariculturists contend with these and a few other species not found here, some causing very severe destruction. In order to indicate the scope and potential magnitude of the problem, we present a short summary of the most severe cases.

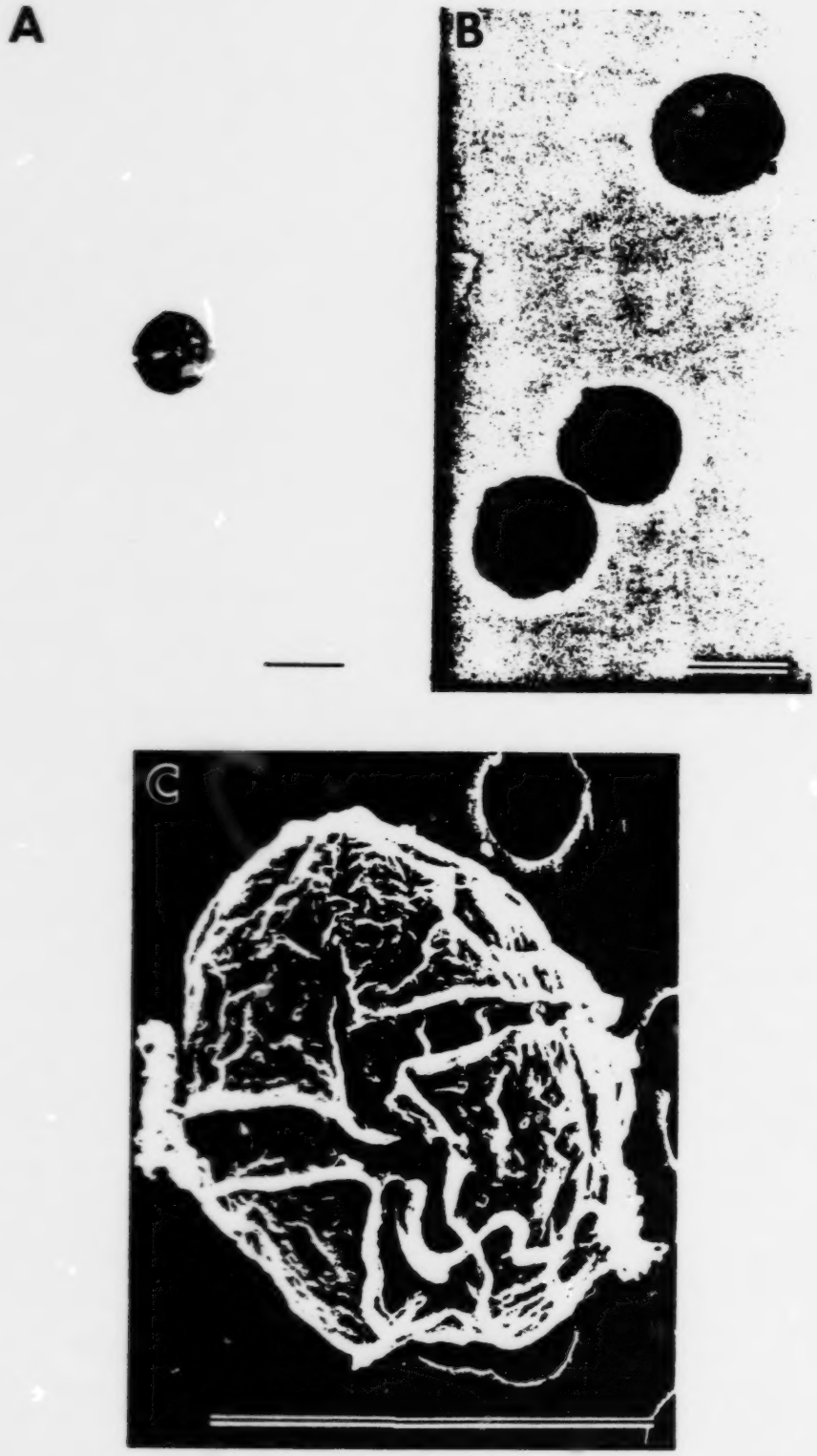

Figure 13. Protogonyaulax tamarensis. (A) Living cell, showing light color and general shape of cell. Note equatorial groove and less flattened shape than P. catenella (above). Photographed using 10X objective. (B) Cells preserved with Lugol's Iodine Fixative. Note dark color and general shape. Rigid outer wall is also visible. Photographed using 40X objective. (C) Scanning electron microscope view of a cell, showing generally more elongate shape and flagella located in grooves in the cell surface. All scales = 20 micrometers.

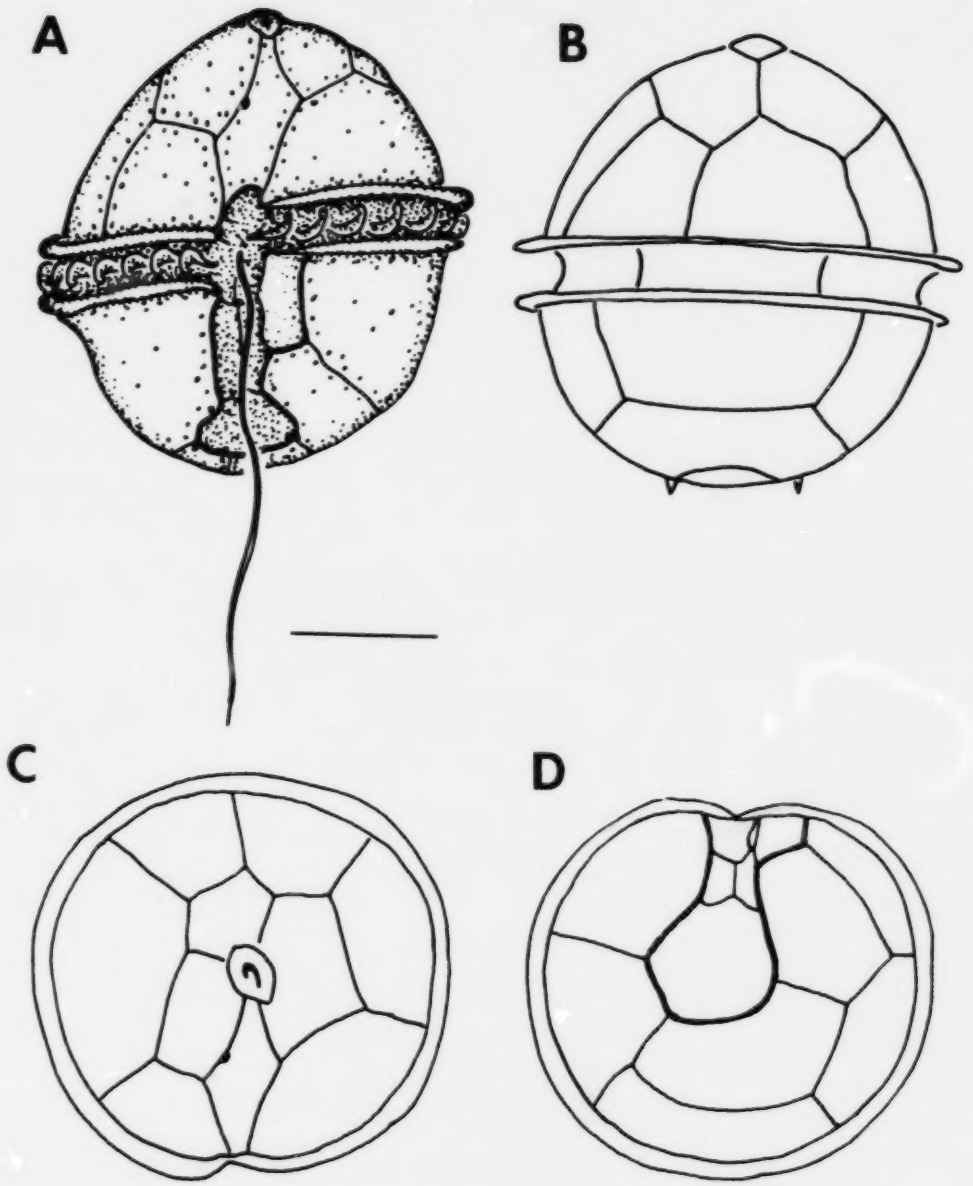

Figure 14. Protogonyaulax tamarensis, showing four views and the arrangement of plates. (A) Ventral (front) view. (B) Dorsal (back) view. (C) Apical (top) view. (D) Antapical (bottom) view. After Taylor, 1975. Scale = 20 micrometers.

Figure 15. Protogonyaulax acatenella, probably just a variety of P. tamarensis. After Taylor, 1975. Scale = 20 micrometers.

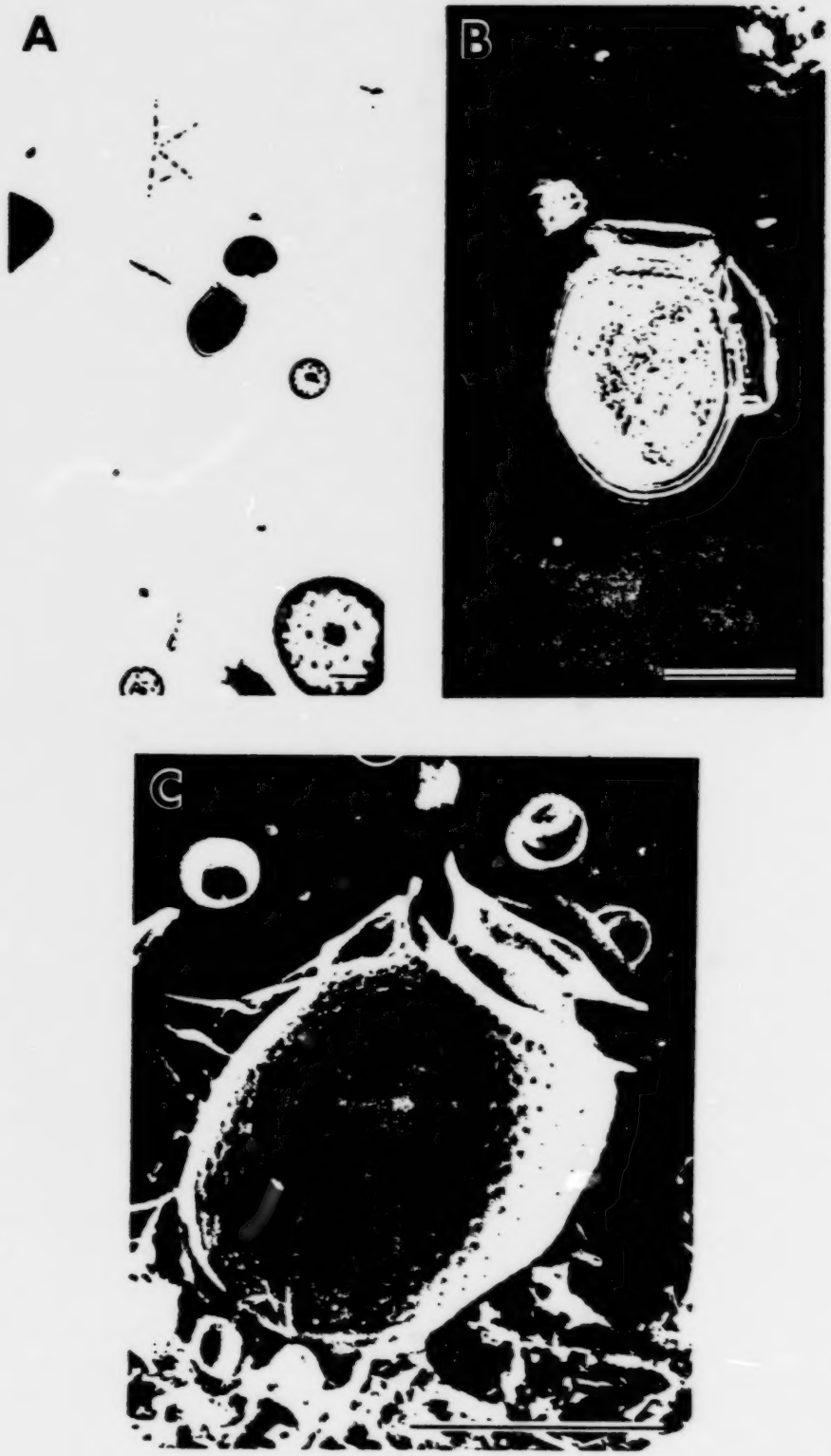

Figure 16. Typical species of Dinophysis. (A) Cell preserved with Lugol's Iodine Fixative. Wall surrounding cell is visible. Photographed using 10X objective. (B) Living cell, showing general shape of cell including delicate flange on one side. Photographed using 40X objective. (C) Scanning electron microscope view of a cell, showing cell shape and surface texture of rigid cell wall. All scales = 20 micrometers.

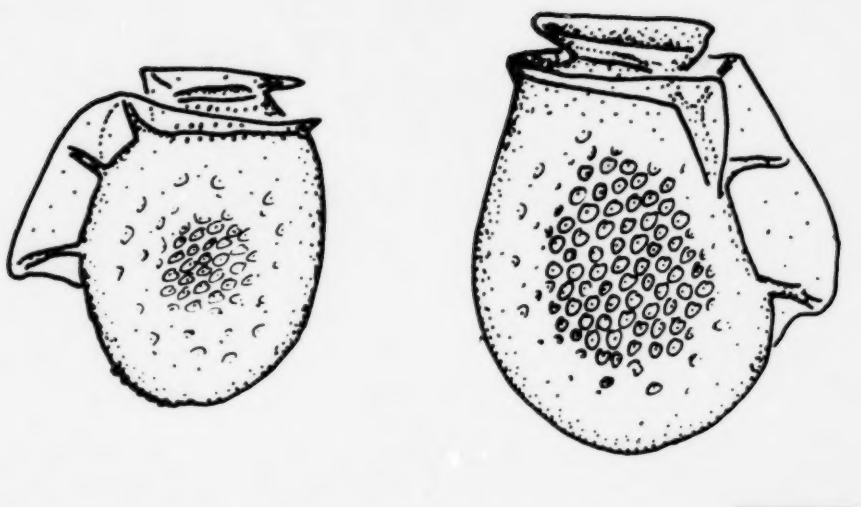

Figure 17. Typical species of Dinophysis. After Abe, 1967. Scale = 20 micrometers.

In the Gulf of Mexico, two dinoflagellate species are severe fish killers. On the west coast of Florida, Ptychodiscus (also known as Gymnodinium) brevis (Fig. 18A) causes widespread fish mortality nearly every year, due to poisons released into the water. Generally, the fish affected are low value, uncultivated species, such as menhaden. Consequently, the principal costs are clean-up and loss of tourism, which can be substantial. In more brackish coastal lagoons from the east coast of Florida to Yucatan, Alexandrium (Gonyaulax) monilatum (Fig. 18B) kills fish and some bottom-dwelling animals, also due to toxin release. The chain-forming A. monilatum closely resembles our own Protogonyaulax catenella, although their toxins are quite different.

The chain-forming but unarmoured dinoflagellate, Gymnodinium catenatum (Fig. 18C), has been associated with paralytic shellfish poison (PSP) outbreaks along the coasts of Spain, the Gulf of California (Mexico), Argentina and southern Tasmania. In 1976, more than a hundred people in Western Europe were made ill by Spanish mussels intoxicated with G. catenatum. This species resembles Protogonyaulax catenella in general shape and in its tendency to form long chains of cells; the most obvious difference is that G. catenatum lacks armour-like plates on its surface.

In northern European waters, the dinoflagellate Gyrodinium aureolum (Fig. 18D) (which resembles Ptychodiscus brevis) has killed fish and some bottom-dwelling animals. Mariculturists are especially concerned because it has killed caged salmon in Norway and Scotland. It appears to bloom when the surface waters have been enriched with nutrients from greater depths. England is where Protogonyaulax tamarensis was first described and paralytic shellfish poisoning (PSP) is known from its northeastern coast. PSP is also a problem in Norway and occasionally on the coasts of Belgium and Portugal. Diarrheic shellfish poisoning (DSP) has occurred in Holland and Spain.

In the tropics, PSP is most common in the East Indies and the Phillipines, but it also occurs in Thailand and India. Many recent fatalities have resulted from eating shellfish (mostly green mussels) that had previously eaten the dinoflagellate Pyrodinium bahamense (Fig. 18E). Some PSP is also known from the tropical Atlantic.

Japan is plagued by several varieties of harmful red tides. A species similar to Gyrodinium aureolum, known as Gymnodium nagasakiense (Fig. 18F) (formerly Gymnodinium "65"), has reportedly killed pearl oysters near Nagasaki. In 1933, pearl oyster losses amounted to $7 million. In the Inland Sea, where so much of Japan's mariculture takes place, a different kind of flagellate, Chattonella (several species) (Fig. 18G), has produced catastrophic kills of

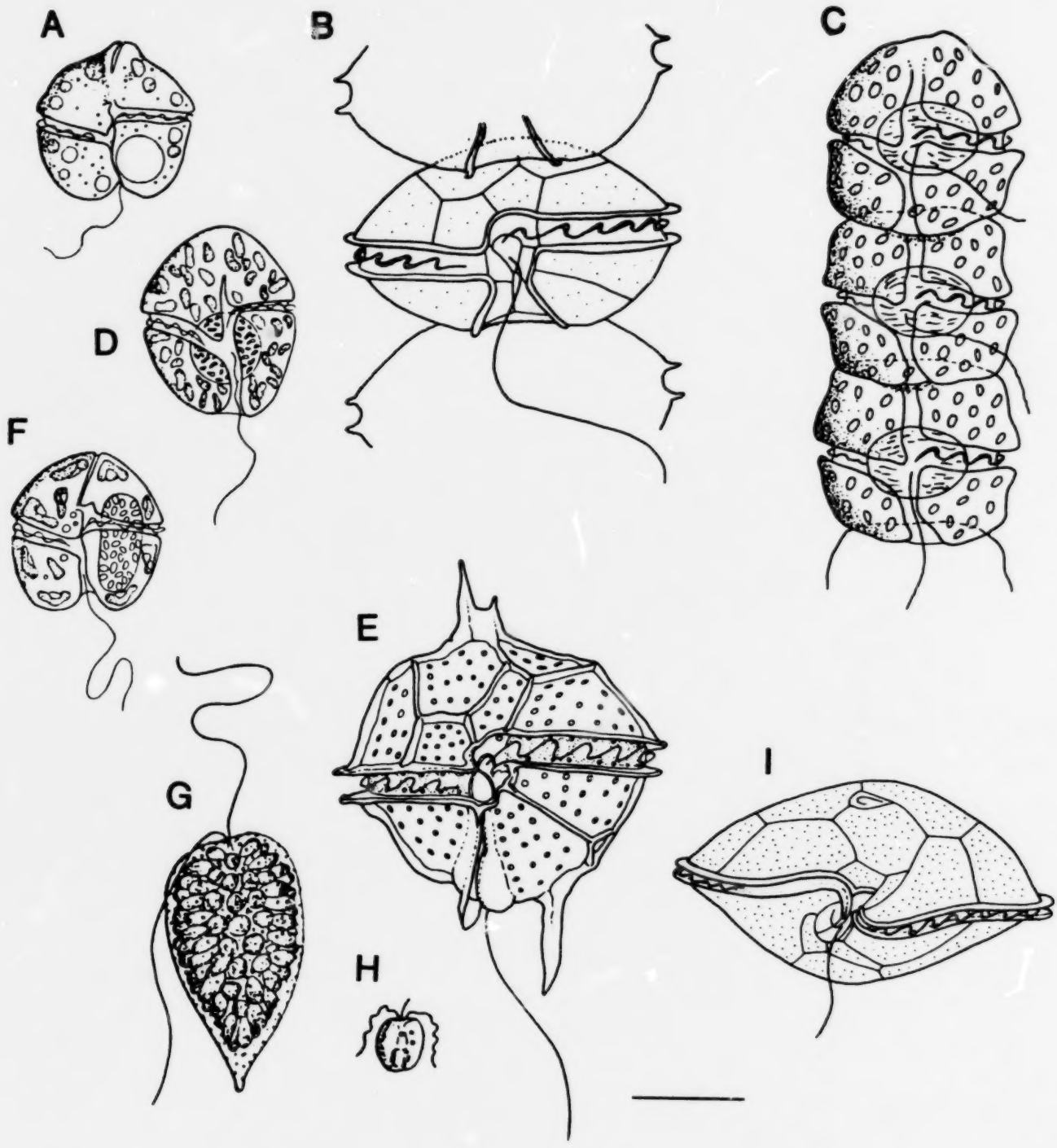

Figure 18. Harmful phytoplankton in other parts of the world. (A) Ptychodiscus brevis. From Taylor, 1985. (B) Alexandrium monilatum. Orig. (C) Gymnodinium catenatum. Orig. (D) Gyrodinium aureolum. From Taylor, 1985. (E) Pyrodinium bahamense. Orig. (F) Gymnodinium nagasakiense. From Taylor, 1985. (G) Chattonella marina. From Taylor, 1985. (H) Prymnesium parvum. Orig. (I) Gambierdiscus toxicus. From Taylor, 1979. Scale = 20 micrometers.

caged yellowtail ($35 million in 1972). Blooms of Chattonella had increased with increasing sewage pollution in the region. Decreasing this nutrient input has brought the incidence down, but not eradicated it. In Japan, PSP has become a widespread problem only in the last decade or so, although more than 100 people died in an earlier incident near Tokyo.

Another type of flagellate, Prymnesium parvum (Fig. 18H), has been a problem in Tilapia fish cultivation in Israel, where it occurs in mineral-rich water (even though its normal habitat is brackish coastal waters). It affects fish by producing substances that alter gill permeability. Similar kills are known from Denmark and New Zealand. A species of Prymnesium has now been observed to occur in Barkley Sound, but not in abundance.

Finally, a very different but related phenomenon is of widespread occurrence throughout tropical coral reef areas. Here, fish that are usually safe to eat become poisonous and potentially lethal to humans as a result of preying on other fish that have eaten seaweeds encrusted with yet another dinoflagellate, Gambierdiscus toxicus (Fig. 18I). This phenomenon is known as ciguatera poisoning and results in severe food and economic losses in places like the islands of the Caribbean and French Polynesia.

So far, British Columbia has been fortunate in being spared these problems.

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APPENDIX I: SOURCES OF INFORMATION AND SPECIES IDENTIFICATIONS

The best authority for information and identifications of species of phytoplankton in British Columbia is Prof. F. J. R. Taylor, Department of Oceanography, U.B.C., Vancouver, B.C. V6T 1W5.

The following literature is helpful in identifying phytoplankton from this area:

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More information on methods of sampling, preservation and identification can be found in:

Sournia, A. (Ed.) 1978. Phytoplankton Manual. UNESCO, Paris, 337 p.

Detailed information about harmful algae can be found in the following volumes:

Anderson, D. M., White, A. W. & Baden, D. G. (Eds.). 1985. Toxic Dinoflagellates. Elsevier, NY, 561 p.

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APPENDIX II: SOURCES OF EQUIPMENT

General-Purpose Equipment

Canlab
131-7080 River Road, Suite 131
Vancouver, B.C. V6X 1X5
(604) 273-7733

Carolina Biological Supply Co
Box 187
Gladstone, OR 97027 U.S.A.
(503) 656-1641

Fisher Scientific Co.
196 W. Third Ave.
Vancouver, B.C. V5Y 1E9
(604) 872-7641

Sargent-Welch Scientific Co.
285 Garyray Drive
Weston, Ontario M9L 1P3
(416) 741-5210

A. H. Thomas Scientific Co.
Vine Street at Third
P.O. Box 779
Philadelphia, PA 19105-0779 U.S.A.
(215) 574-4500

Western Scientific Co. (VWR Scientific)
P.O. Box 7900
San Francisco, CA 94120 U.S.A.
(415) 468-7150

Wildlife Supply Company (WILDCO)
301 Cass St.
Saginaw, MI 48602 U.S.A.
(517) 799-8100

Specialized Oceanographic Equipment

General Oceanics, Inc.
5535 NW 7th Ave.
Miami, FL 33127 U.S.A.
(305) 754-6658

InterOcean Systems, Inc.
3540 Aero Ct.
San Diego, CA 92123 U.S.A.
(619) 565-8400

Kahl Scientific Instrument Corp.
P.O. Box 1166
El Cajon, CA 92022 U.S.A.
(212) 665-1603

Ogawa Seiki Co., Ltd.
Tokyo Central P.O. Box No. 1618
Tokyo, Japan
Tel.: Tokyo (363) 4521

Research Instrument Co.
R.R. #2
Guelph, Ontario
(519) 822-1547

APPENDIX III: HETEROSIGMA FACT SHEET

(Prepared for distribution at the Pacific Salmon Farmer's Association meeting in West Vancouver, July 10, 1986)

Full Name: Heterosigma akashiwo (Hada) Hada - ("akashiwo" is the Japanese name for "red tide"; Hada is the name of the Japanese scientist who named it, once under another name, once under this name).

Also Known As: Heterosigma inlandica Hada; Chattonella akashiwo (Hada) Loeblich; "Flagellate X" of Gowen. All references to Olisthodiscus luteus, except those by N. Carter and Y. Hara, also apply to this species.

Description: The organism occurs as microscopic, bean-shaped single cells, usually 12 to 22 micrometers (thousandths of a millimetre) long, propelled by two very fine, whip-like flagella which arise from the side of the cell, nearer to the front, one pointing forwards and one trailing behind. The cells turn slowly as they swim forward. The shape varies from being smoothly oval (flattened in the same plane as the flagella) to being bumpy and potato-like in outline. When in poor condition the cells become rounded. Each cell contains usually 20 or fewer (but may have up to 50) greenish-brown bodies termed chloroplasts, which house the light-energy gathering photosynthetic machinery (the cell uses sunlight and chemical nutrients to grow, like land plants and seaweeds). Small shining dots on its surface are mucus-producing bodies, termed mucocysts.

Reproduction: The cells reproduce by simply splitting in half, approximately once per day (twice a day at 20°C and salinities of 10 to 15 parts per thousand). They also produce masses of rounded cells, surrounded by mucus, that sink to the bottom and may act as dormant "seeds", although it is not known how long they can survive in this state.

Nutrition: As noted, these cells are plant-like in that they use sunlight for energy during the day and absorb chemical nutrients from the seawater. They require the following: nitrogen in one of several forms, including nitrate, ammonia or urea (but they can flourish in as little as 6uM of total nitrogen, less than the diatoms that might compete with them), phosphate (3-5 uM per litre is preferred, which is relatively high), iron and other trace metals and vitamins, particularly manganese and vitamin B12. The latter two may be derived chiefly from bottom muds or river inflow.

Environmental: Heterosigma is tolerant to an unusually wide range of salt content and can survive in 2 to 50 parts per thousand (usual B. C. coastal waters range from 20 to 32 except near rivers) over a wide temperature range, from 3 to 30°C. It prefers salinities of 15 to 20 and temperatures at the higher end of the range, but can achieve concentrations of hundreds of millions per litre in temperatures lower than 15°C. It can adapt well to low and high light intensities.

Behaviour: In response to light, the cells aggregate in dense masses near the surface during the day. These surface concentrations can be 5 to 10 meters thick (diver observations). In order to be able to aggregate, calm conditons are needed. They may migrate down deeper at night, 0.5 to 1 meters per hour, probably to obtain additional nutrients.

Time of Blooms: In B. C., most blooms occur between May and July. Heterosigma has bloomed in the English Bay/Howe Sound area every year that we have sampled since the late 1960s. In Japan and Rhode Island, blooms have also occurred in August. In spring, there is a major, beneficial diatom bloom and Heterosigma usually blooms after the diatoms have declined. In Japan, one study indicated that blooms may occur when the bottom water becomes low in oxygen, which supposedly increased the release of metals and vitamins from the sediments.

Distribution: A detailed, broad scale survey of its occurrence has not yet been made in B. C. However, in the course of other sampling we have observed regular blooms, initially in areas influenced by the Fraser River, i.e., northwards on the east side of the Strait of Georgia and south to Lummi Island, with occasional spread across to the west side of the Strait. We suspect that it may like river influence, in view of the timing (peak run-off) and extent of the blooms. However, it also occurs later in Barkley Sound and other less estuarine areas.

The species is also known from Japan, the east coast of North America and Europe.

Comments: Heterosigma has been circumstantially linked to fish kills before: in our region it may have caused kills at Lummi Island in 1976 and in Nanoose Bay in 1985. In 1981, in the Inland Sea of Japan, it killed 8,000 yellowtail, as well as many flatfish. Although a specific toxin has not yet been identified, the full spectrum of substances produced by this organism has not been determined. Possibly, it produces harmful products only under certain conditions. The large quantities of mucus on the fish gills could originate from Heterosigma's mucocysts or it may be a response by the fish. Related

organisms (Chattonella spp.) are known to produce compounds which alter gill permeability.

Heterosigma has been found to harm oyster larvae indirectly, by producing a substance that encourages the growth of harmful bacteria.

Despite the regular occurrence of dense blooms in B. C. waters, wild fish have apparently not been killed, presumably because they can avoid the densest patches. This suggests that if fish pens are deep enough, caged fish can be protected. Also, shading the pens may induce the flagellates to migrate out of the pens, assuming that currents do not offset this. However, if a toxin is released into the water, this may not help. Agitation of the water might prevent local surface aggregations but may disrupt the cells, increasing mucus release. Pumping up deeper water may have short-term, emergency benefits but is likely to enrich the surface waters with nutrients, aggravating the problem in the long term. Total physical isolation raises other problems but may be unavoidable. The Japanese solutions to these problems should be carefully studied. Chemical control agents that do not harm other organisms are not known.

It is virtually certain that blooms of this organism will occur again next year, following the spring diatom bloom. If the kills in 1981 were because of increased caged populations, similar events can be expected.

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APPENDIX IV: A PROCEDURE FOR SAMPLING PHYTOPLANKTON

Introduction

The following standardized sampling procedure has been developed to: (i) assist salmon farmers with monitoring their own farm sites; and, (ii) be incorporated into an area-wide monitoring program that should provide the ability to forecast the development of levels of phytoplankton hazardous to farm operations.

Two kinds of sampling are required:
(A) qualitative - to determine what species are present; and,
(B) quantitative - to determine how many of each species are present.

(A) Qualitative Sampling - What Species are Present?

1. Take a Vertical Haul with a Plankton Net
   Select a permanent sampling location at or near your pen site. Lower the net to a depth of 20 m or about 1 m above the bottom if your site is shallower than 20 m. Pull the net to the surface at about 0.5 m per second or slower. (If the net is pulled too quickly a compression wave froms in front of the net which forces water around the net rather than through it.) After lifting the net above the surface of the water, lower the bottom 3/4 of the net into the water again and lift quickly--this helps wash the material inside the net into the bottom of the net. Repeat this procedure--each time lowering less of the net into the water until only the very bottom end of the net is lowered. To complete this washing down process, squirt water through the net--from the outside--working from the top to the bottom of the net. Now the contents of the net are concentrated in the bottom of the net, or the "bucket" of the net, if the type of net in use has one. Now drain the contents of the net or the bucket into a sample jar. Add preservative (Lugol's solution)--unless you wish to inspect the sample live--and label the jar--location (salmon farm "X"), vertical haul - 20 m to surface (0 m) or 10 m to (0 m) etc., date, time of day.

2. Sample Selected Depth Ranges with a Closing Plankton Net
   A vertical haul from 10 m to the surface will provide an indication of species occurring within the depth range of most salmon net pens. A vertical haul from near bottom up to 10 m (then close the net) will provide an indication of species present below net pens. The use of a closing net allows for qualitative sampling over any predetermined range of depths--i.e. 40 to 10 m, 20 to 10 m, 10 to 0 m, etc. (see below for more detail).

(B) Quantitative Sampling - How Abundant are the Species?

If your qualitative sample reveals the presence of a dangerous phytoplankton species, you must establish whether it is increasing or decreasing in abundance, whether it is abundant enough to cause a problem, and, as these organisms tend to occur in discrete layers, where in the water column organisms are located. Changes in abundance are easily established by comparison with your last sampling records. Be sure you record any results you get or the fact there were no dangerous plankton.

To take a quantitative sample it is necessary to collect water from each of several depths. We recommend samples be taken at the surface, and at 1, 5, 10 and 20 m depth. Each sample must contain a known volume of water in which the plankton has not been allowed to settle.

Quantitative samples are taken with a "water bottle"; there are several different types including Kemmerer, Van Dorn, Nansen, etc. These types of bottles are lowered--in the open position--to the selected depth and a messenger is then dropped down the wire to trip the closing mechanism in the bottle. A sample of known volume is thereby taken at a selected depth. The bottle is then lifted to the surface and any selected volume drained from a tap on the side of the bottle. We recommend a sample of one litre be taken for plankton analyses. (Obviously a sample can be drawn at the same time for any other analyses--0_2, salinity, etc.) As above, label the sample and add preservative if desired.

Two less expensive but adequate methods of taking a quantitative sample are: (i) use a "Student Water Sampler"; or, (ii) the bottle and cork method.

The bottle and cork method consists of a narrow-neck bottle (e.g. a one litre wine bottle) weighted at the bottom and attached to a line. A cork attached to a separate line is inserted into the bottle. The bottle is lowered to the selected depth and the cork and is pulled out to allow the bottle to fill.

If the sample is not going to be analysed "fresh", it should be preserved with Lugol's solution then allowed to sit undisturbed for 24 hours. Then the supernatant should be siphoned off until the settled plankton resides in 100 ml of fluid.

Seasonal Frequency Of Sampling

In order to ensure coverage of those seasons in which plankton blooms are most likely to occur, we suggest the following: start in March and take samples every two weeks until mid April; from then to late November, weekly samples should be taken.

What To Do When Dangerous Plankton Are Present But Sampling Has Not Revealed The Location In The Water Column

Plankton blooms can occur in patches on the surface and in very narrow horizontal layers in the water column. It is probably that dangerous plankton reside in a narrow band which was missed in sampling at 1, 5, 10 and 20 m depths. When your quantitative samples fail to document species found in the total vertical haul, you can usually locate more precisely where in the water column the plankton of interest is by using a closing plankton net. For this reason we recommend use of a closing net sampler (see figure) for all qualitative analyses.

If you wish to do this type of sampling, we suggest you divide the top 20 m into 2 to 4 hauls. For example, you may do a haul between 20 and 15 m, another between 15 and 10 m, a third between 10 and 5 m, and a last haul between 5 m depth and the surface. This type of sampling will establish the 5 m portion of the column in which the phytoplankton occur.

The technique for sampling is much the same as that outlined in the earlier qualitiative sampling section. The major difference is that when you have hauled the net through the portion of water column you are interested in sampling, you drop a metal messenger down the line to close the net before the net is hauled to the surface.

Lugol's Preservative

The best preservative for phytoplankton is Lugol's Iodine Fixative. It is prepared by dissolving 100 g potassium iodide in one litre of distilled water, then dissolving 50 g of crystalline iodine in this. Finally, 100 ml of glacial acetic acid are added, and any precipitate is decanted or filtered out. These chemicals can be obtained through most scientific supply companies. This preservative is added to the sample until the sample is a weak tea colour (about one drop fixative per one ml of the sample). This will not only preserve cells, but it will colour them dark brown, which makes them somewhat easier to see under the microscope.

Selection of Plankton Nets

A net like that described in the first part of this Manual will serve well for general qualitative sampling. The more expensive closing net--often referred to as the Birge Closing Net--can be used for both total vertical hauls and selected depth range hauls. Any net selected should have Nitex mesh size number 28 or 30. (Although this mesh size is larger than the size of some of the smaller toxic species--i.e. Herterosigma akashiwo at 5 microns--it will collect sufficient numbers to determine their presence.)

Care of Plankton Nets

It is very important that you not allow your nets to dry at any time before you have cleaned them. (These nets dry in minutes on a hot summer day.) Small phytoplankton, left on the cloth while it dries, stick to it and are almost impossible to remove. This quickly renders the net useless.

This sampling procedure has been drafted by Messrs. T.G. Halsey and E.A. Black in consultation with Dr. "Max" Taylor, Department of Oceanography, University of British Columbia.

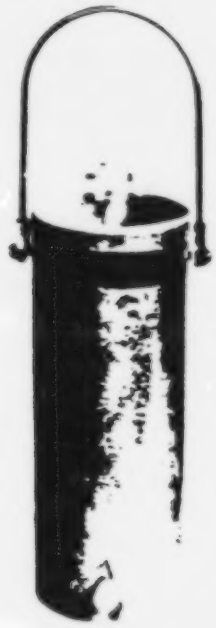
The xeroxed illustrations of A Plankton Net for Students and the Student Water Sampler are taken from the Research Instrument Co. catalogue. The illustration of the Closing Plankton Net is taken from Wildco, Wildlife Supply Co. catalogue.

R.I.C. STUDENT WATER SAMPLER

Our very own invention. It's built of P.V.C. or clear plastic; no metal parts inside the sampler. Low-cost, yet efficient water sampler; no messenger needed. As the sampler is lowered, the upper and lower plexiglass doors swing open to allow the water to pass through the bottle. When the desired sampling depth is reached the doors swing shut and remain tightly closed as the sampler is raised, preventing contamination of the sample. There is a valve to draw off water.

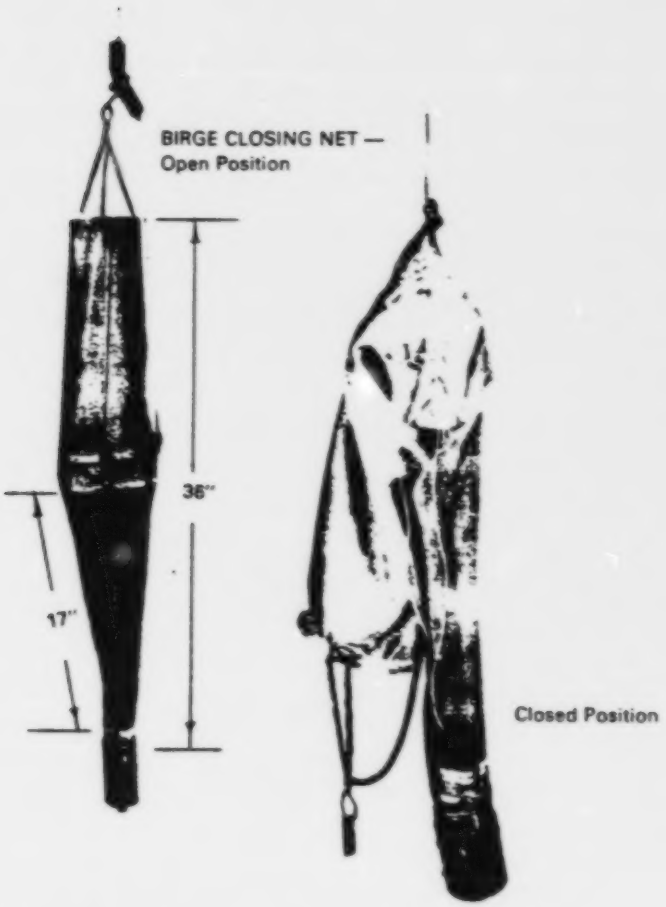
It comes complete with 50 feet of polypropylene line, and can be ordered with or without a sturdy carrying case finished in tough acrylic paint. Stock sizes are: P.V.C. - 1 liter, 2 liters, 5 liters, 10 liters. Clear plexiglass) 1 liter, 2 liters, 5 liters, 10 liters, 12 liters, 20 liters, 30 liters. Other sizes on request.

1-2 liter size comes with 50 feet line. 5 liters and over with 100 feet line. Clear plexiglass models only sold with carrying case.



R.I.C. Student Water Sampler

BIRGE STYLE — CLOSING NET SAMPLERS



- Reliable nickel plated brass closing mechanism
- Used for horizontal or vertical sampling applications
- 5" dia. (13 cm) mouth openings
- Includes 2⅛" dia. x 3⅛ " long Plankton Bucket with 9 sq. inch filter area (5807 mm²)